



Solar System Scale & Size

Grades: K-8

Prep Time: ~20 Minutes

Lesson Time: ~60 minutes



WHAT STUDENTS DO: Explore Size and Distance Relationships among Planets

Students will create a model of the solar system using beads and string, and compare planetary sizes using common types of fruit and seeds. In this collection, this lesson follows the simple balloon model in Lesson 2, covering the relationships of size and distance in the solar system. It reinforces concepts students have just encountered in terms of scale and distance and the way in which models assist us in understanding.

NRC CORE & COMPONENT QUESTIONS

WHAT IS THE UNIVERSE & WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth's Place in the Universe

What are the predictable patterns caused by Earth's movement in the solar system?

NRC ESS1.B: Earth and the Solar System

INSTRUCTIONAL OBJECTIVES

Students will be able

IO1: to construct a simple model

See Section 4.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.



1.0 About This Activity

This activity is part of the Imagine Mars Project, co-sponsored by NASA and the National Endowment for the Arts (NEA). The Imagine Mars Project is a hands-on, STEM-based project that asks students to work with NASA scientists and engineers to imagine and to design a community on Mars using science and technology, then express their ideas through the arts and humanities, integrating 21st Century skills. The Imagine Mars Project enables students to explore their own community and decide which arts-related, scientific, technological, and cultural elements will be important on Mars. Then, they develop their concepts relating to a future Mars community from an interdisciplinary perspective of the arts, sciences, and technology. <http://imaginemars.jpl.nasa.gov>

The Imagine Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (See *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative. This five-part sequence is the organizing tool for the Imagine Mars instructional series. The 5E stages can be cyclical and iterative.




2.0 Materials

Required Materials

Please supply:

For Solar System Bead Model

- Large craft pony beads in 11 suggested colors (1 of each listed below) per student
 - Yellow (Sun)
 - Opaque Red (Mercury)
 - Cream (Venus)
 - Clear Blue (Earth)
 - Clear Red (Mars)
 - Black (Asteroid belt)
 - Orange (Jupiter)
 - Clear Gold (Saturn)
 - Dark Blue (Uranus)
 - Light Blue (Neptune)
 - Brown (Pluto - dwarf planet)
- 4.5 meters of string for each student
- Small piece of cardboard to wrap the Solar System string around (10 cm X 10 cm) after the project is complete
- Measuring tapes (with centimeters), meter sticks, or other metric measuring tools

 **Teacher Tip: Buying the String:** To prevent tangling frustrations, a specific type of string is strongly suggested. You will be looking for string that is thicker than twine, but thinner than yarn. It is 100% cotton, 4-ply knitting and weaving yarn that many times can be bought on a large cone.

 **Differentiation Tip: Solar System Beads** For younger students or to speed up the activity:

1. The string may be pre-cut and a set of Solar System beads may be put into a plastic baggie for each student.
2. A pre-measured marking grid can be put on a table top so the students can mark their measured distances, then tie off the beads.
3. If students will be marking their string ahead of time for each planet, tape newspaper to the floor to prevent marking the floor. 4 cm will need to be added to each planet distance measurement to accommodate tying of the bead (double knot).



For “Farmer’s Market Solar System (Class Demo)

- 1 Honeydew Melon
- 1 Cantaloupe
- 1 Lemon
- 1 Lime
- 2 Grapes
- 1 Macadamia Nut
- 3 Peppercorns

Please Print:

From Student Guide:

- | | |
|----------------------------------|-----------------|
| (A) Solar System Predictions | – 1 per student |
| (B) Solar System Beads | – 1 per student |
| (C) Planet Bead Calculations | – 1 per student |
| (D) Farmer’s Market Solar System | – 1 per student |

Optional Materials

From Teacher Guide:

- (E) Farmer’s Market Solar System Key
- (F) Solar System Cut-outs
- (G) “Solar System Size and Scale” Assessment Rubrics
- (H) Alignment of Instructional Objective(s) and Learning Outcome(s) with Knowledge and Cognitive Process Types



3.0 Vocabulary

Astronomical Unit (AU)	a standard measurement used within the solar system; Earth is 1 AU from the Sun
Models	a simulation that helps explain natural and human-made systems and shows possible flaws
Planet	a sphere moving in orbit around a star (e.g., Earth moving around the sun)
Prediction	the use of knowledge to identify and explain observations or changes in advance (NSES, 1996)
Relationship	the connection among and between objects
Scale	a measurement that will represent a standard measurement for comparison among objects
Solar System	our solar system has 8 planets moving in orbit around the sun, along with dwarf planets such as Pluto, comets, asteroids, and moons; some other stars, like the Sun, have solar systems (planets and other bodies orbiting them) too
System	an organized group of related objects or components that form a whole (NSES, 1996)

4.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.
- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.
- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).



Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

WHAT IS THE UNIVERSE & WHAT IS EARTH'S PLACE IN IT? <i>NRC Core Question: ESS1: Earth's Place in the Universe</i> What are the predictable patterns caused by Earth's movement in the solar system? <i>NRC ESS1.B: Earth & the Solar System</i>			
Instructional Objective <i>Students will be able</i>	Learning Outcomes <i>Students will demonstrate the measurable abilities</i>	Standards <i>Students will address</i>	Rubrics in Teacher Guide
IO1: to construct a simple model	LO1a. to compare the relative size and distance of the Earth, Earth's Moon, and Mars LO1b. to use a calculated scale for establishing relative distances LO1c. to predict using a model LO1d. to explain scientific processes (scale, use of models)	NSES: UNIFYING CONCEPTS & PROCESSES Grades K-12: A1: Systems, order and organization A2 Evidence, models, and explanations NSES (D): EARTH & SPACE SCIENCES: Earth in the Solar System Grades 5-8: D3a	

This activity also aligns with:

NRC SCIENCE & ENGINEERING PRACTICES

- 2) Developing and using models
- 5) Using mathematical and computational thinking

NRC SCIENCE & ENGINEERING CROSSCUTTING CONCEPTS

- 4) Systems and system models

21ST CENTURY SKILLS

- Critical Thinking and Problem Solving
- Communication
- Collaboration
- Initiative and Self-Direction



5.0 Procedures

PREPARATION (~45 minutes)

Constructing the “Solar System Beads”

- A. For each student, have available: string cut in 4.5 m lengths, colored beads, cardboard, tape, and measuring tools.

Printing:

- B. Handouts (A) – (D) in the Student Guide at the end of this lesson.

Preparing the “Farmer’s Market Solar System”

- C. Have fruits on hand for students to examine, or provide cutouts found in (F) *Farmer’s Market Solar System, Low-cost Cutouts*

STEP 1: ENGAGE (~10 minutes)

Making Predictions

- A. Ask students to imagine taking a vacation, visiting all of the planets and other cool destinations in the solar system. When we plan a vacation or trip here on Earth, we have to think about how far away things are, and how long it will take us to get to each place. Ask students to start with their predictions of how long it would take to reach each planet or other body from Earth by drawing relative distances. They should use (A) *Solar System Predictions* in the Student Guide at the end of this lesson. Their predictions are represented by a drawing of what students believe the distance to be between the planets (to the scale of a regular size piece of paper). Ask them to draw all of the planets, including the Sun and Asteroid Belt, showing what they believe to be the relative distances between these bodies. Students may need a reminder about all of the planets and their order in the Solar System.

Ask students to make a second prediction, this time with additional information. Explain to them that if we were to drive a car at highway speeds to the Sun, it would take about 163 years to get there. If we were to travel at the same speed to Mars, it would take 81 years. To get to dwarf planet Pluto, it would take 6,357 years! Obviously, we travel faster than a car when we use a rocket to blast off (e.g., to Mars, spacecraft travel at ~12,000 miles per hour), but the highway comparison gives students an idea of relative distance.



🍏 Differentiation Tip: For older or more advanced students, have students calculate mathematically.

🍏 Curiosity Connection Tip: For making a connection to NASA's Mars Rover "Curiosity," please show your students additional video and slideshow resources at: <http://mars.jpl.nasa.gov/participate/marsforeducators/soi/>

STEP 2: EXPLORE (~10 minutes)

Finding the Scale

- A. Hand out *(B) Solar System Beads Instruction Sheet* and *(C) Planet Beads Calculation Worksheet*.
- B. Have students complete the table in *(C) Planet Beads Calculation Worksheet*, converting the various AU distances to centimeters, and complete the chart provided.
- C. Have students measure and cut a piece of string 4.5 meters long.
- D. Using the calculated cm distances, tie the bead onto the string using a double knot.
- E. When students finish the activity, review the models, then wrap the Solar System string (with beads) around the cardboard holder.

🍏 Differentiation Tip: Solar System Beads For older or more advanced students, measurements can be made each time from the Sun to the planet and tied on after each measurement. Thus, no additional 4 cm length will be needed in completing the model in this way.

STEP 3: EXPLAIN (~20 minutes)

Explaining the relationship between their predictions and results.

- A. Have students complete the questions on *(C) Planet Beads Calculation Worksheet*.



STEP 4: ELABORATE (~10 minutes)

- A. For this step, allow students to examine the fruits, nuts, and peppercorns (or cut-out shapes in the Teacher Guide). Explain to students, now that they have an idea of the scale and distance between planets, that it will also apply to the size of the planets. Ask them to predict the size of each planet in the solar system using these materials and the *(D) Farmer's Market Solar System Worksheet*. They may use some fruits, nuts, and peppercorns more than once. Ask them to work collaboratively to discuss potential sizes.
- B. Once students are finished, using *(E) Farmer's Market Solar System Key*, reveal the Farmer's Market Solar System for students to compare their results.

STEP 5: EVALUATE (~20 minutes)

Assessing Proposed Strengths and Weaknesses of Missions.

- A. By completing the final two questions on *(D) Farmer's Market Solar System Worksheet*, students will reflect on what they have learned. In a group discussion, ask them to compare their initial predictions with what they now know. This conversation is a good time to reinforce the idea that science is all about not knowing at first, but finding ways (e.g., using models, making predictions) to gain new knowledge. It is also a good time to reinforce that they are capable of being scientists by following their curiosity, making predictions, collecting data, and revising their original ideas with new information.

6.0 Extensions

Students may be curious about why Pluto is no longer considered a planet, and our solar system now has 8 planets instead of 9 as we once thought. Have a discussion about classification—looking at common characteristics to group like things. Explain how, before we began exploring the solar system with spacecraft and before we had more powerful telescopes and other tools, we didn't realize that Pluto was a lot more like other bodies, called dwarf planets, than it is like the 8 planets in our solar system. It's a good opportunity to discuss that science is about continuously revising our models as we discover new things.



7.0 Evaluation/Assessment

In the Teacher Guide, use the (G) “*Solar System*” *Rubric* as a formative assessment that aligns with the NRC Framework, National Science Education Standards, and the instructional objective(s) and learning outcomes in this lesson.

8.0 References

- Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. New York: Longman.
- Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications*. Colorado Springs: BSCS.
- Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington, DC: The National Academies Press.
- Lantz, H.B. (2004). *Rubrics for Assessing Student Achievement in Science Grades K-12*. Thousand Oaks: Corwin Press.
- Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.
- National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.
- The Partnership for 21st Century Skills (2011). *A framework for 21st century learning*. Retrieved March 15, 2012 from <http://www.p21.org/>